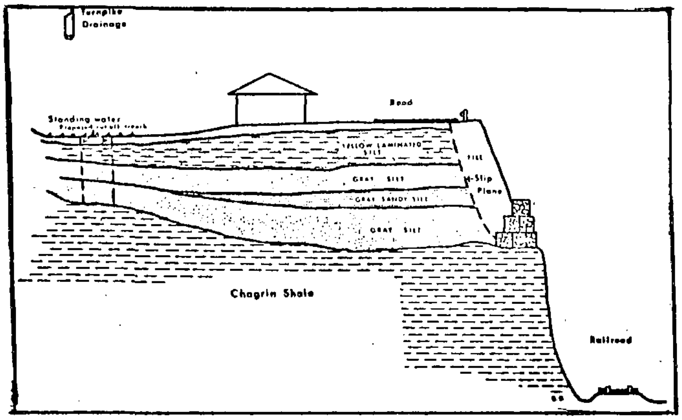

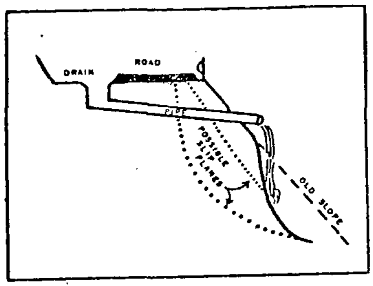

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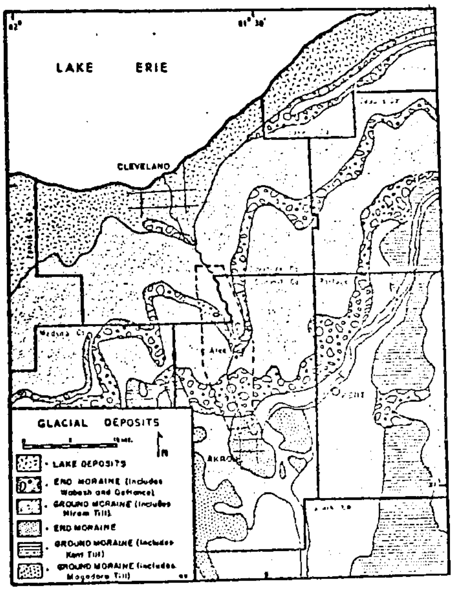

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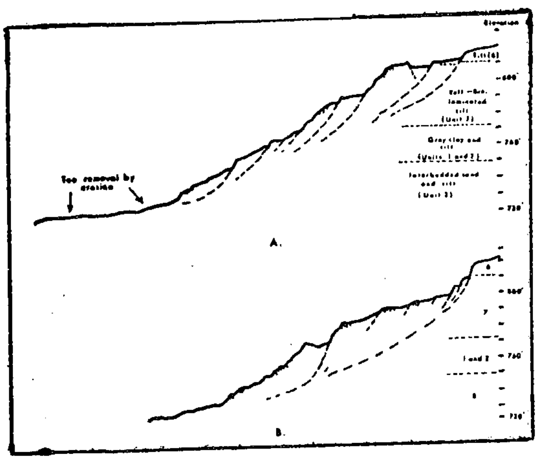
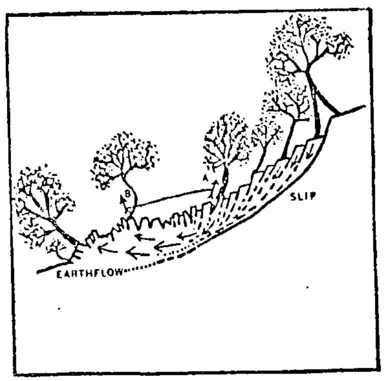




THE OHIO ACADEMY OF SCIENCES

FORTY-EIGHT ANNUAL

FIELD CONFERENCE

APRIL 28, 1973

ASPECTS OF THE ENGINEERING-ENVIRONMENTAL GEOLOGY IN THE LOWER CUYAHOGA RIVER VALLEY, OHIO

GEORGE D. GARDNER

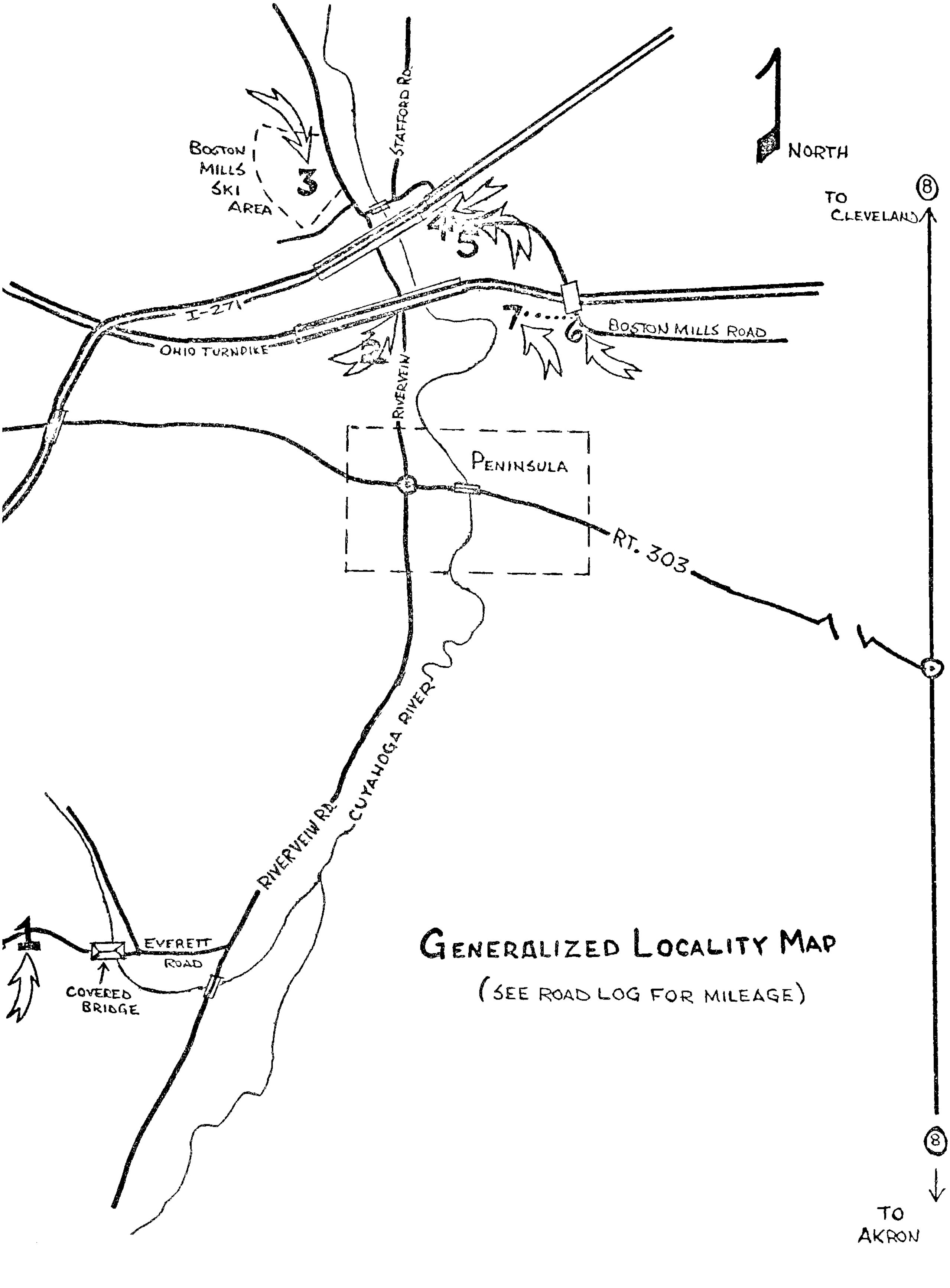
GENERAL ANALYTICS, INC.

ROAD LOG

Mileage	Directions
0.0	- Start mileage from redlight at the intersection of Rt. 303 and Riverview Road in Penninsula. Head south on Riverview Road.
2.8	- Turn right on Everett Road (follow sign to Hale Farm Village). Continue on Everett Road, take left fork in the road and go over the covered bridge.
3.9	- STOP 1- Everett Road slide on south side of the road.
	- Retrace route back to redlight in Penninsula.
0.0	- Continue north through the redlight on Riverview Road.
1.0	- STOP 2- Riverview Road slide beneath the Ohio Turnpike bridge.
	- Continue north on Riverview Road.
1.5	- Take left fork in road, stay on Riverview Road.
1.8	- STOP 3- Boston Mills Ski Area on West side of road. Piping slope on northern most slope.
	- Go south on Riverview Road retracing route to the fork in the road (Boston Mills Road).
2.1	- Turn left onto Boston Mills Road and go over the bridge which crosses the Cuyahoga River.
2.38	- Keep right at the fork in the road (stay on Boston Mills Road).
2.7	- STOP 4- Erosion of embankment adjacent to I-271 bridge abutement.
	- STOP 5- Just around the bend from Stop 4, the Schultz slide.
	- Continue east on Boston Mills road, note signs of unstable slope conditions on the road and surounding slopes.

Mileage	Directions
3.6	- STOP 6 and STOP 7-
	- Stop 6- in the roadcut just beyond bridge which overpasses the Turnpike.
	- Stop 7- Leave car parked and LOCKED, walk back up toward the Turnpike Overpass. Take path which parallels the Turnpike heading west. Walk along fence to slope overlooking the river valley.

- As you are leaving you can continue East on Boston Mills road and intersect Rt. 8. Route 8 leads north to Cleveland and south to Akron, and has interchanges for both I-271 and the Ohio Turnpike. Follow signs.



Generalized Locality Map

(SEE ROAD LOG FOR MILEAGE)

TABLE OF CONTENTS

INTRODUCTION

Site Evaluation and Land-use Planning

A Growing Need

George D. Gardner- Kent State University*

An increasing population and an expanding economy necessarily foster an increase in land development. As continual development exhausts prime sites, man must expand into marginal areas which were previously avoided because of various adversities (i.e. rugged terrain, lack of readily available water, adverse ground conditions related to roads, waterlines, sewers, ect.). Within the last decade mounting concern for man's impact upon the environment has brought to focus the fact that man can no longer blight his resources with reckless abandon and remain unscathed. Expansion into marginal areas coupled with concern for environmental impact necessitates a site evaluation prior to the instigation of final design and construction of any proposed development. Alterations in design may become necessary to accommodate adverse conditions revealed in site evaluation. In some cases design alterations may involve an increase in construction costs, costs which may become prohibitive to development. Site evaluation might also reveal that detrimental environmental effects caused by design, location, or method of construction outweigh the necessity of the development. It would then be more beneficial

* Present address- General Analytics, Monroeville, Pa.

to redesign, change the method of construction, or abandon the site. No matter how unfavorable the added costs and time may seem, it is ultimately cheaper to learn of site adversities prior to development, than to learn the "hard way" by becoming a case history for some engineering journal.

Evaluation can also be used to determine the criteria for site utilization without any specific development in mind. In this case the geologic, geohydrologic, and soils characteristics are employed to ascertain what types of developments are compatible to a site. Such evaluations are commonly called LAND-USE PLANNING. Land-use planning can be integrated with other factors including projected population, industrial, commercial, and agricultural growth and needs forming the REGIONAL PLAN. When presented in an easy-to-understand fashion, such as colored maps, land-use planning can be an invaluable contribution to regional planning. Land-use planning input from the geoscience and geotechnical fields will prove more vital as encroachment upon marginal areas increases, and as the intricacies of environmental impact are better defined.

Geology in Site Evaluation and Land-use Planning

The specific role of geology in site evalution is two-fold. The first is to determine the ability of the proposed development to accept the physical conditions on the site (engineering geology), and the second is to determine the ability of the site and the surrounding areas to accept the proposed development (environmental geology). For example, a site may be evaluated as totally suitable for a specific development in respect to subsurface conditions, slope stability, drainage, etc. (engineering geology); however, the soil materials mat be such that adverse slope erosion and siltation of streams may occur, or, that development (excavation) may locally lower the water table drying nearby wells, swamps, or cause local perennial streams to become intermittent. In this hypothetical case the site proved satisfactory for the development, but the development proved adverse to the site and surrounding areas.

In land-use evaluation the distinction between engineering and environmental geology is not as well defined. The terms are often used interchangeably because both engineering and environmental aspects must be integrated to develop a coherent land-use plan. Conducting a land-use or site evaluation requires that the observer combine ample knowledge and perceptiveness with a sound foundation in the basic geologic and geohydrologic principles.

Determining Behavioral Characteristics of Soils

Environmental-engineering evaluation requires determination of the geologic, geohydrologic, and behavioral characteristics of the ground materials, particularly the soils, and the use of these characteristics to ascertain problems which might be encountered when developing in these soils. Of course, geologic and geohydrologic factors cannot, and will not be divorced from discussion of the sites. The trip will emphasize the importance of preliminary, on-the-site evaluations which can be conducted quickly and at minimum cost. Such evaluations are invaluable in assessing feasibility, environmental impact, and for planning further testing programs. The localities to be visited are areas which already suffer from problems, mainly slope instability, and are representative of the typical problems which occur in the soils of the lower Cuyahoga River valley.

The behavioral characteristics of the soils can be determined by various methods ranging from qualitative field examination to expensive laboratory techniques. For preliminary, on-the-site evaluations the more elaborate techniques are impossible; however, simple methods have been devised to estimate soil behavioral characteristics. One useful method is soil classification. While many soil classifications are available, the one which will be utilized here is the 'Unified Soil Classification System' (U.S.C.S.). The U.S.C.S. was originally devised by Arthur Casagrande for military airfield site investigations (Casagrande, A., 1948) but has since found widespread application in most aspects of soil engineering. The U.S.C.S. integrates grain size, grading, sorting, and plasticity characteristics into its organization. Many behavioral characteristics that commonly recur in the various soil types have been compiled from hundreds of analyses and experiences. Qualitative estimates of bearing capacity, susceptability to frost action, erodability, permeability, resistance to piping and shear, etc., are some of the characteristics compiled. Classifying a soil by the U.S.C.S. ultimately requires laboratory analysis; however, accurate classification can be accomplished in the field after a little practice. Thus, the U.S.C.S. offers a simple method of in-field classification which in turn can be used to determine the behavioral characteristics of a soil. This can be an invaluable asset in site evaluation and land-use planning when coupled with the geologic and geohydrologic characteristics. Appended to the field guide is the Unified Soil Classification System, its laboratory and field criteria, the engineering characteristics, and a soil components and properties table. These tables were reproduced from the "National Engineering Handbook," Section 8--Engineering Geology, with permission of the Soil Conservation Service.

GEOLOGY

Physiography

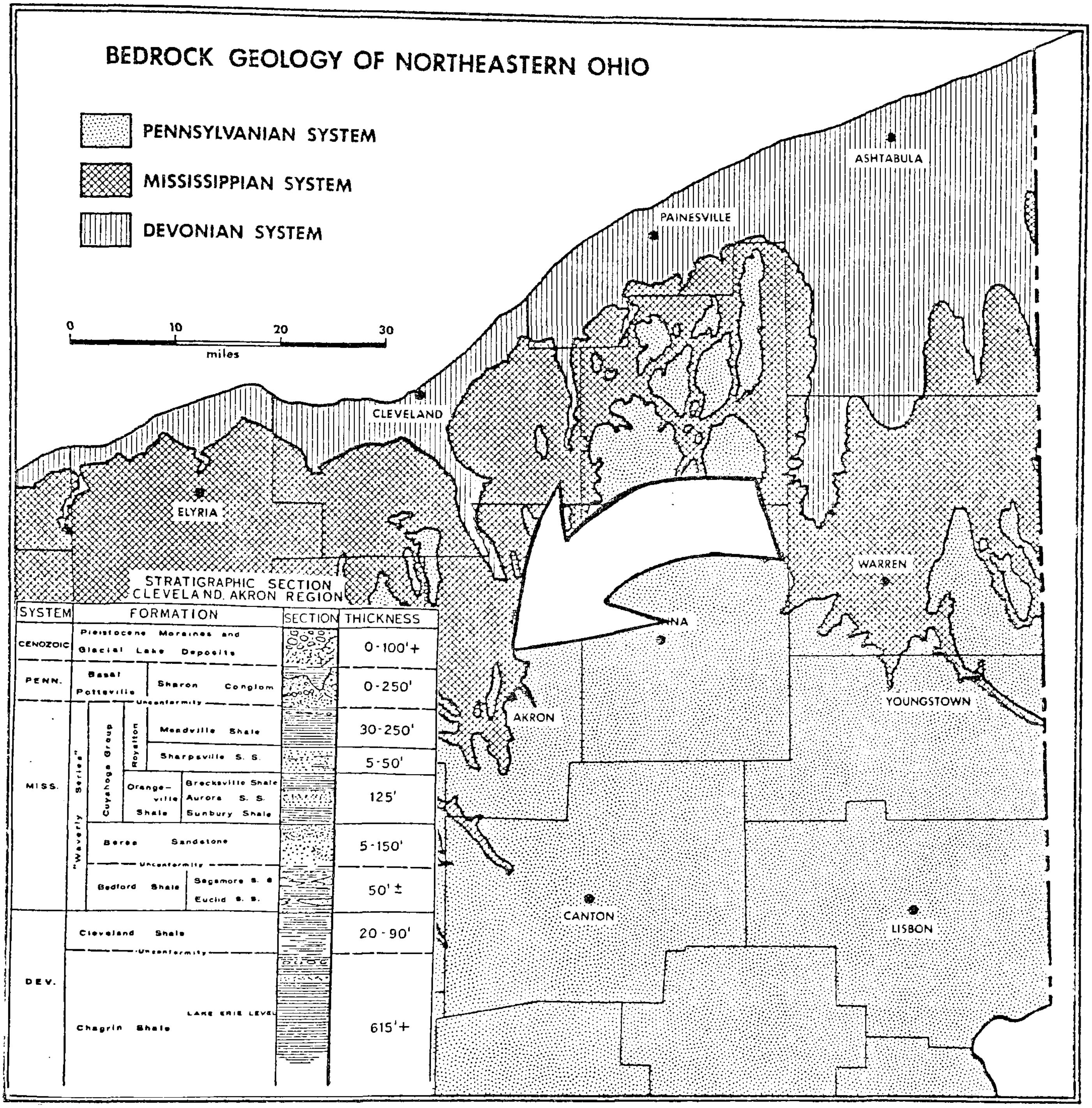
Physiographically, the lower Cuyahoga River is located within the northwest portion of the intensely dissected Allegheny Plateau. Geologically, the Cuyahoga valley is formed in the glacial deposits which fill a larger, much deeper bedrock valley carved by a precursor river into mid-Paleozoic shales and sandstones. The present location of the river is directly controlled by the glacial deposits, and indirectly by the bedrock surface. The topography of the glacial deposits generally follows the highs and lows of the bedrock, with deposits usually much thicker in valleys and thinner on highs. For this reason, much of the Cuyahoga River flows concordantly within a buried pre-Pleistocene bedrock valley, as do many of the other streams and rivers in northeastern Ohio. In general, the present valley form is a function of geomorphic processes associated with stream erosion and mass wasting in the glacial materials.

Pre-Pleistocene

Pre-Pleistocene erosion exposed upper Devonian to Pennsylvanian age bedrock composed primarily of sandstones, siltstones and shales. The rock strata dip gently southeastward and form a relatively flat upland surface which was deeply dissected by north flowing streams and rivers prior to glaciation. One such river valley underlies the presnt course of the Cuyahoga River north of Akron. Within the lower Cuyahoga River valley the bedrock comprises a small portion of the exposed surface area. Figure 1 summarizes the bedrock stratigraphy within the field trip area.

Pleistocene Deposits

During the last two million uears continental ice sheets have repeatedly advanced from Canada, invading areas of the northern United States (Clark and Stearn, 1968, p. 380). Illinoian stage outwash deposits are reported to exist below the Wisconsinan in the northern part of the lower Cuyahoga valley (White, 1953, p. 36-39). Pre-Wisconsinan glacial deposits are not exposed in the southern part of the valley, although they may exist in the thick sediments of the buried valleys below the present stream and river level. In some area, such as Brecksville, these sediments are estimated to be over 700 feet thick (Frank, 1969, p. 1-4), possible extending to sea level in the buried valley at Cleveland. The glacial map (figure 2) shows the distribution of the glacial materials. The actual geology of the deposits within the valley is very complex and conventional methods of stratigraphic correlation cannot be used over a large area. A brief description of the various unconsolidated deposits encountered in the valley is given below.



SYSTEM	FORMATION				SECTION	THICKNESS
CENOZOIC	Pleistocene Moraines and Glacial Lake Deposits					0-100'+
PENN.	Basal Potteville	Sharon Conglom				0-250'
	Unconformity					
MISS.	"Waverly Series"	Cuyahoga Group	Royalton	Meadville Shale		30-250'
				Sharpsville S. S.		5-50'
			Orange-ville Shale	Brecksville Shale Aurora S. S. Sunbury Shale		125'
		Berea Sandstone				5-150'
		Unconformity				
		Bedford Shale	Sagamore S. S. Euclid S. S.			50' ±
DEV.	Cleveland Shale					20-90'
	Unconformity					
	Chagrin Shale	LAKE ERIE LEVEL				615'+

Figure 1. Generalized bedrock geology and stratagraphic section for Northeastern Ohio (approx. location of field trip area designated by white arrow). Figure adapted from:

Guide to the Geology of Northeastern Ohio, P.O. Banks and R.M. Feldmann (eds.), Northern Ohio Geological Society, 1970, pp. 6.

Ohio Intercollegiate Field Trip Guides 1950-51 - 1969-70, G.W. Frank (ed.), K.S.U. Printing Service, 1969, pp. 1-6.

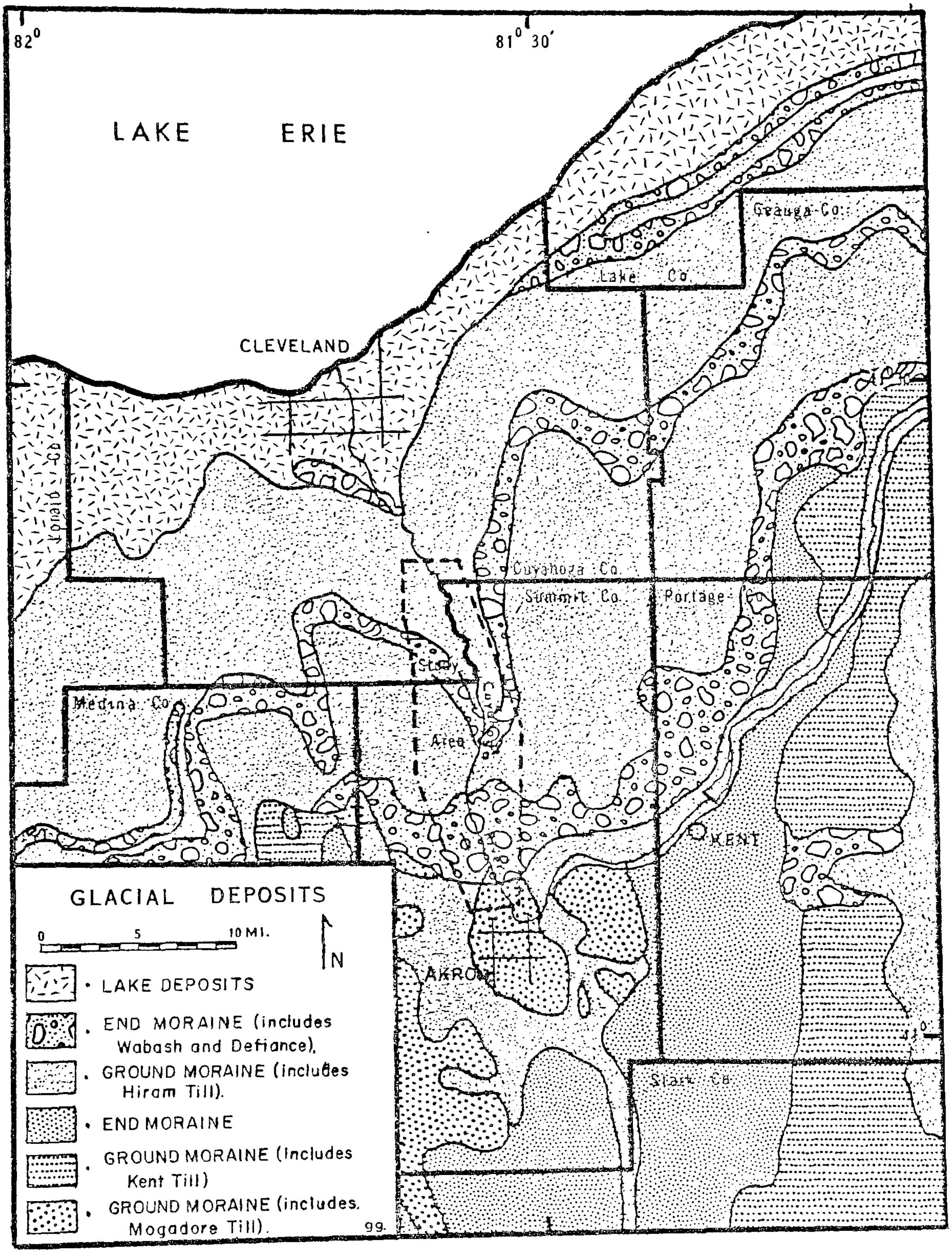


Figure 2. Glacial map of study area and vicinity (White, 1953b).

Unconsolidated Deposits

Tills- The glacial tills are characterized by high clay contents, poor sorting, and lack of stratification. The stratigraphy of these deposits (figure3) was based primarily on position in sequence and distinctive sand-silt-clay ratioes (Shepps, 1953, p. 34-38). The tills most often classify as low plasticity clay, CL soils in the U.S.C.S., and usually contain boulder, pebbles, and cobbles. Unconfined compressive strengths are usually greater than 3.5 tons/sq. ft. The tills, particularly the Hiram, may have joints which extend vertically through its entire thickness. These joints are commonly filled with calcareous material.

Ice contact deposits- The Defiance and Wabash End moraines represent points where the ice stagnated and accumulated material at the terminus. Such deposits usually stand as linear topographic highs, either as ridges or a series of humocky hills. Post glacial erosion subdued these features within the valley by removing all but a few remanents along the valley walls. The deposits which make up end moraines often are varied both in composition and structure. Particle size can range from clays to boulders. The morainal materials exposed within the valley appear as thick (30 or more feet) unstratified till-like deposits containing significant amounts of boulders, sands, and silts in a matrix of clay (CL, CI-ML).

Outwash and River deposits- The deposits which characterize

EPOCH	STAGE	SUBSTAGE: present nomenclature (White, et al., 1969)		SUBSTAGE: earlier nomenclature (White, 1960)	UNIT
PLEISTOCENE	WISCONSINAN	Woodfordian	"late"	Cary	Hiram Till
			"middle"		Lavery Till
			"early"		Kent Till
		Farmdalian			
		Altonian		Tazewell	Mogadore Till

Figure 3. A general comparison of substage terms for the Wisconsinan Stage (Wittine, 1970, p.11).

the fluvial and glacio-fluvial materials are: lenses of bedded and cross-bedded sands and gravels (GW,SW,GP,SP,GM, SM), interbedded lenses of sand, gravels, and silt (SP,GP,GM, SM.ML), and finely cross-bedded silts (ML).

Lacustrine and Ponding deposits- The standing-water deposits within the valley are mainly gray clayey silts, silty clays, and silts (CL, CL-ML, ML); and yellow-brown silts and clayey silts (ML, CL-ML). Many of the silts show distortion and contortion of the bedding. Many of the deposits, particularly those in Penninsula Township, contain selenite crystals.

STOP- 1 Everett Road

The slide observed on Everett Road is one of many which occur on the slopes of this tributary valley. Examination of the soil reveals that the sliding mass is composed mainly of silty clays and clayey silts (CI, CI-MI, MI). Reference to the Unified Soil Classification Engineering Properties tables shows that these soils characteristically have low to medium permeability, high erosion potential, fair to very poor ability to take plastic deformation without shearing, and only fair shearing strength. Principle sliding movement occurs along a logarithmic spirally shaped slip plane (high angle at the head, low angle in the middle and lower sections), the base of which is no lower than the road. This fact is evidenced by: the topographic posture of the slide; the undisturbed nature of the road and slope beyond; the presence of a CI type soil at the base. Stress distribution diagrams for slopes (Zaruba et.al., 1969, p. 18) show the principle maximum stress vectors concentrating in the middle and lower slope, with stress direction becoming more horizontal in the lower slope. Thus, a weak clay unit with a low friction angle, located in the lower slope, would enhance basal shear, and cause a logarithmic spirally shaped slip plane. Secondary movements have developed on the main sliding mass, adding to the complexity of the topographic posture.

The triggering mechanism of the slide was probably the undercutting of the toe of the slope during road construction.

Of equal importance in slide propagation is the geology and geohydrology of the slipe. Characteristically the low permeability silty clays are interbedded with lenses of more permeable silty sands (SM) and clean sands (SP, SW). During the wet season*pore water pressures can build within these lenses, significantly reducing the shearing resistance of the soil. In many cases this alone is enough to initiate failure. At this site the added impetus of toe removal was required for failure. Once movement was initiated, disturbance of the flow paths along shear zones increased the pressure and saturation levels, accelerating the slope degradation processes, and caused increasingly complex slide-flow situation. The initial movement and ensuing reduced stability left this slope vulnerable to effects of increased saturation and pore water pressures. Thus, during the wet months of late winter and early spring the slide periodically moves out onto the road.

Areal survey shows that much of the slope area along this tributary valley is unstable. The present status of this slide is not one of pressing concern. The slide itself is not endangering private property or placing undue strain on the local environment. Amelioration of a slide such as this would prove more costly than simple pushing the mud off the road once or twice a year. However, any further development planned within this area must consider the slide conditions

* wet season refers to months of greatest ground saturation

encountered here, from the standpoint of proper design, construction methods, and environmental impact. Factors to be considered include slope stability, the likelihood of piping, and the effects of defoliation on slope erosion, and on stream siltation.

STOP- 2 Riverview Road

A landslide on Riverview Road beneath the Ohio Turnpike bridge has repeatedly mobilized and disrupted the road and railroad. Sliding involved activation of interbedded gray silts and clays (CL, CL-ML, ML), yellow-brown silts (ML), and gray silty sand (SM). Mobilization has occurred along steep, nearly vertical slip planes (see accompanying diagram). Reference to the U.S.C.S. Properties tables indicates that most of the soils in the profile (ML,SM,CL-ML) have medium to low permeabilities, poor resistance to shear deformation, only fair shearing strength, and possible piping problems. Examination of the adjacent, foliated slope reveals no apparent instability problems, yet the conditions on this slope are almost identical to those on the slope which has repeatedly failed. The dilemma is more clearly understood when the history of the site is known. The first instance of slope instability occurred shortly after wind-damaged trees were removed (pushed over). The trees aided slope stability by sapping water from the soil, and actually binding the slope together. The shearing strength of the soils was probably weakened by the ground disturbance when the trees were overturned, and by removal of the binding ability and sapping functions of the roots. Another factor was the addition of water into the groundwater flow system of the slope by runoff from the Ohio Turnpike bridge. Pipes and ditches from the bridge empty into the low area behind the slope (note the presence of cat-tails). The effect is to increase the seepage levels above those experienced before construction of the bridge. Thus, the geologic, geohydrologic, and behavioral characteristics of the soils were conducive to failure. The removal of the trees, ground disturbance and increased pore water pressures acted in concert to trigger the first slope failure. Initially, the failure also may have been enhanced by piping which later propagated the larger rotational slide by undercutting the slope.

Following the first failure, the slide scar was refilled behind pyramidal-shaped rock-filled cribs. The fill material was the debris from the previous slide. During the late winter, water seeped along bedding planes in the silts and silty sands until it met the semipermeable fill material at the old slip plane. The fill became saturated along this plane, pore water pressure increased, and the slope failed again, removing

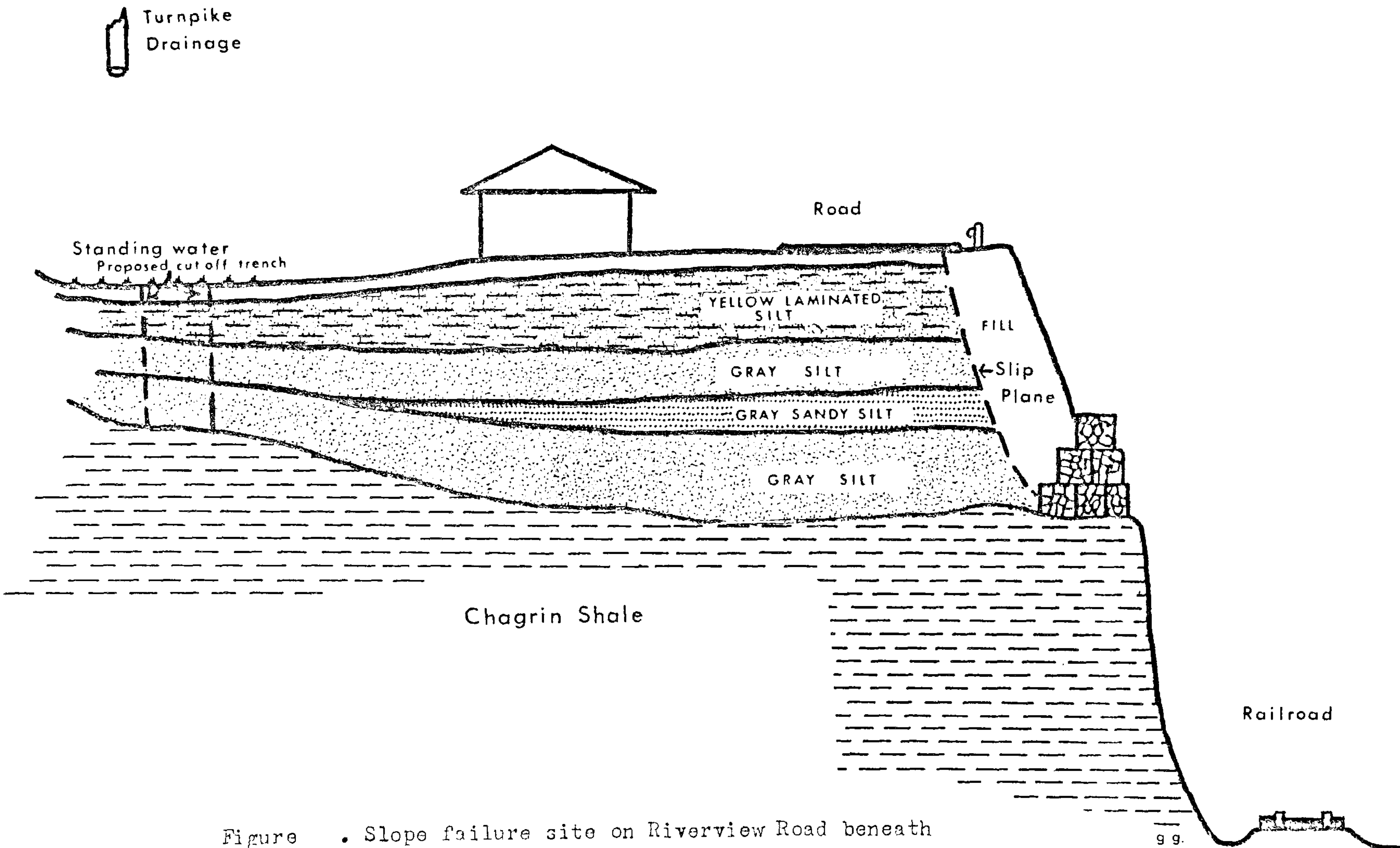


Figure . Slope failure site on Riverview Road beneath the Ohio Turnpike bridge.

part of the road and burying a section of the railroad.

The method suggested to correct the slide conditions was to intercept the ground water seepage with a cutoff trench parallel to the slope at the crest, and to redirect surface drainage from the Turnpike. A layer of gravel placed horizontally at the base and vertically up the scar was also recommended to improve the long-term stability of the slope by reducing pore water pressures.

STOP- 3 Boston Mills Ski Area

Piping is a process in which a slope is undercut by removal of material at the base, causing the slope above to calve. The materials involved in piping at this locality are interbedded lenses of clean sand (SP) with sandy silt (SM) resting on a bedrock surface of shale. Referring to the U.S.C.S. Properties tables, both the SP and MI soils are given as very susceptible to piping and erosion with relatively high and medium permeabilities respectively. These characteristics, coupled with the geologic and geohydrologic conditions (interbedded lenses of sand and silt resting on a sloping shale surface with groundwater seepage downslope along the soil-bedrock interface into the clean sand) set the stage for the piping. Prior to development, the slope had a thick foliage cover, a well developed soil profile, and no piping problems. Defolation and removal of the soil mantle exposed the underlying sand and silt beds, allowing the ground water to freely escape from the base. This initiated the piping which rendered the slope useless for skiing, caused financial loss to the developer, and created a potential hazard.

While it is easy to assume the role of "Monday morning quarterback," a simple site analysis may have predicted such a problem, and produced valuable suggestions regarding methods to avoid the outcome. One such method would have been to install vertical cutoff drains high on the slope to reduce downslope seepage. Another less expensive and possibly more effective method would have been to develop narrow, transversing trails leaving the lower slope foliated, rather than defoliating the entire slope. The narrow trails could have been easily covered with a clayey surface with proper drainage installed beneath the surface at critical locations.

The problem now is not "what should have been done," but what can be done to correct the situation. Piping is one of the most difficult slope problems to ameliorate. The first step is to determine the extent of the piping and potential piping materials in a thorough site evaluation. It may be necessary to regrade the slope in such a manner to either eliminate the problem, or to reduce it to a scale which can be more easily repaired.

This stop also contains exposures of other types of sediment which are common to the slopes of the valley. Of particular interest are the gray and yellow-brown (gypsiferous) silts and silty clays. Contorted bedding and slump ball features are also found in the exposures near the T-bar lift.

STOP- 4 Boston Mills Road beneath the I-271 bridge

At Stop 4 a drainage design is observed which is adequate for most soil conditions, except those at this site. For the most part the soils at this site are silty clays, clayey silts, and some sands (CL,CL-ML,ML,SM). Reference to the U.S.C.S. Properties tables indicates that these soils have a very high erosion potential. This fact is quite obvious at this site. Running water has undermined the riprap filled drainage ditch, piping the soil beneath the riprap, causing the drainage to by-pass the culvert. Water now runs across the road and into the stream, increasing the discharge and sediment load of the stream. If the water entered the culvert as designed, the storm drains would rapidly silt-up, causing more problems.

Again, proper site evaluation could have forecasted such results. Boring logs used in the design and construction of I-271 revealed the presence of the silty soils in the vicinity of this abutment. Soil conditions were known, however, oversight, nonfamiliarity with the behavior of these soils, and/or bureaucratic processes probably fostered the inadequate design observed at this stop.

STOP- 5 Boston Mills Road--Schultz slide

The slide at this site occurs in the same type of soil materials witnessed at the previous Stop. The situation here is somewhat similar to that observed at Stop 1, the Everett Road area; however, this slide effects private property and dwellings owned by Mr. F. Schultz. The geologic, geohydrologic, and soil behavioral characteristics are, once again, conducive to sliding. The soils, clayey silts, silty clays and an occasional sand lense (CL, CL-ML, ML, SM, SP) characteristically have high erosion and piping potential, fair shearing resistance, and only fair-poor ability to take plastic deformation without shearing. These soils occur in thick (1'-3') to thin (1"-1') interbeds and lenses on this hillslope. The triggering mechanism initiating sliding probably was undercutting the toe of the slope during road construction. Planes of weakness also could have developed earlier by natural undercutting by the stream. However, the current configuration of the slide indicates sliding impetus was provided by the roadcut.

As in the Everett Road slide (Stop 1), increased pore water pressure during the wet season plays a key role in the degradation of this slope by periodically reactivating the slide. The slide itself is rotational and retrogressive in nature with a near circular arc shaped slip plane, complexed by secondary slip planes developed within the sliding mass. The maximum depth of the primary slip plane is estimated to be 30 feet beneath the center of the slope. The difference in symmetry between the Everett Road slide and this one is explained by the location and occurrence of the gray clay ûnit in the Everett slide. In the Everett road slide the low shearing strength clay unit is located at the base of the slope, thus, stress distribution within the slope causes failure along the clay unit as discussed in STOP 1. The materials in the Schultz slide are quasihomogeneous (different beds acting as one unit), therefore, the shear planes develop along the more ideal circular arc.

Again, the necessity of site evaluation is personified by example. Although it would be ridiculous to suggest evaluation for every inch of secondary road planned, a cursory evaluation, as exemplified today, would prove invaluable. As you drive to STOP 6 take notice of; the "bumps" in the road with newly asphalted, semicircular shaped areas; the topographic posture of the slopes both above and below the road; the attitude of the trees on those slopes. Almost the entire slope on Boston Mills Road from STOP 5, ½ mile up the road toward STOP 6 is mobilized to some extent. A trained observer could have easily reconnoitered the situation with a simple traverse. Boston Mills road, built many years ago, was probably built in the best possible manner within the limits of terrain, construction techniques, and finances. However, the increasing use of automobiles spawns an increasing demand for more and better highways. Highway department budgets usually require frugal expenditures with little room for major financial loses due to unforseen repairs. Better highways coupled with desire for resonable long-term maintenance costs demands better evaluation than has been exhibited in the past, not only within the Cuyahoga valley, but for most other highways.

STOP 6 Boston Mills Road Near the Ohio Turnpike Overpass

The roadcut at Stop 6 exposes soil materials similar to those observed at the previous locations (CL, ML, CL-ML, with an occasional lens of SM or SP). The point of interest at this stop is the comparison of the topographic posture of the slopes on opposite sides of the road. Slope degradation processes have decidely affected the north facing slope more than the south facing one. This is caused, in part, by the increased and prolonged saturation conditions on the north facing slope. The south facing slope receives direct radiation from the sun most of the daylight hours all year, while the north facing slope receives no direct sunlight until late spring, and then only for a few hours. This greatly affects the depth of saturation of the soils on this slope. The south facing slope is usually noticeably drier. The exposure factor is even more prevalent along Interstate roadcuts leading into the valley.

STOP- 7 Slope adjacent to the east Ohio Turnpike bridge abutment

The slope adjacent to the eastern bridge abutment of the Ohio Turnpike exemplifies the stability problems common throughout the lower Cuyahoga valley. The geology, geohydrology, and behavioral characteristics of the soils is difficult to determine by simple field investigation because of the vegetative cover and lack of clean outcrop. However, distinctive surface features are exhibited by this slope which implicate soil conditions, geology, and geohydrology, are conducive to sliding. The value of recognizing potential problem areas and distinguishing various land-use qualities from the geomorphology and botany cannot be overemphasized. Ability to do so allows the observer to formulate hypotheses which he can later test when investigating the site in more detail. Such a step is an essential starting point in any evaluation, and of value by providing focal points and guidelines for further investigation. Aerial photography is a very powerful tool with which to decipher geology, recognize geohydrologic and botanical features, and detect problem areas. Recent advancements in technology and public availability of remote sensing data have greatly increased the value and importance of such investigations. Large and small land areas can now be viewed as environmentally, geologically, and botanically interacting areas much more quickly and easily than before.

Field evidence indicating active movement on this slope is multifold. The ground surface is scarred with numerous tension cracks and slide scarps. The lineations caused by these scars are quite apparent on airphotos. The attitudes and trunk shape of the trees typify those on slumping slopes. The history of slide movement can often be deciphered from the trunks and growth patterns of the trees. The geology, determined by field observation, is similar to that seen at the other stops, and is likewise conducive to sliding. A highly generalized outline of the soil stratigraphy is given on the accompanying diagram. Sliding is, for the most part, rotational and retrogressive in nature, with the major shear surface estimated to have a maximum depth of 40', lying at approximately 19° from the horizontal (which, coincidently, is the laboratory determined residual angle of internal friction). Sliding was probably initiated by oversteepening and undercutting the toe by the Cuyahoga River which used to run along this flank of the valley before rerouting. Movement is continued by undercutting the toe by headward eroding intermittent valleys, with the possibility of piping in the sand units at the base of the slide. Increased pore water pressures during the wet season also plays a key role in slide activation. Excavation of the impermeable till above the slope for Turnpike fill enhances the seepage by exposing the silty soils and providing for water impoundment in the recharge area. Absence of trees, which can sap significant volumes of water, also enhances seepage and pore water pressure effects.

As one can see, the entire slope is mobilized. The extent of slope mobilization in the area typifies movement on may other slopes within the valley. A small "bump" on the road may actually be a small part of an extensive slide system, such as seen on Boston Mills Road. Other roads with similar conditions include Highland Road, Columbia Road, Yellow Creek Road, and others. If these conditions were recognized and anticipated in planning the construction of the various roads and Interstates which cross the valley, man hours, materials, costs, and delays may have been reduced considerably.

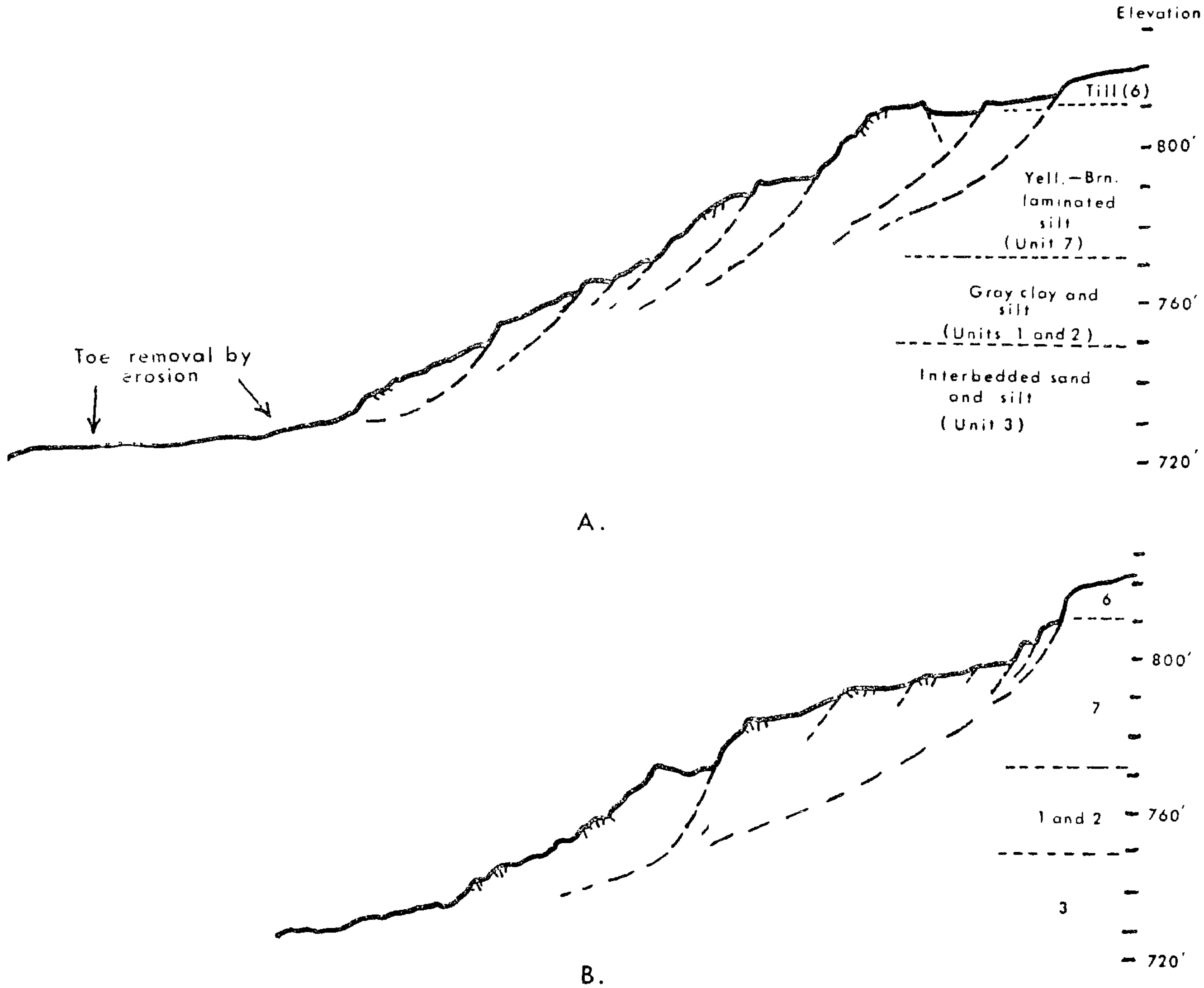


Figure . Two profiles of the east valley wall just south of the Ohio Turnpike bridge.

SUMMARY

We have witnessed a few problems typical of those related to the geology, geohydrology, and soil conditions within much of the lower Cuyahoga River valley. Future development plans within the valley must consider these conditions and associated problems prior to location, design, and construction to assure safety, economy, and environmental compatability.

Land-use planning would facilitate proper development regarding best-use and environmental impact factors on a regional scale. Domestic and/or industrial development will require more and better roads, sewers, utilities, and other supplemental necessities. Within the lower Cuyahoga valley, few roads have not been plagued by slope failure problems to some extent. Proper construction and improvement of future roads will prove a costly venture, as witnessed today. The low permeability characteristics of many of the soils will necessitate sewers or holding tanks if extensive development is planned. Stringent erosion control will be required because of the erosive nature of the soils. Tens of thousands of tax dollars are spent every year dredging sediments from the river channel in Cleveland. Much of this sediment enters the river downstream from Akron. Defoliation within the drainage basin of the lower Cuyahoga River, if unchecked, will greatly increase present sediment load and deposition by tens, hundreds, or even thousands of times (Robinson, A.R., 1970, p. 188).

Thus, development of much of the lower Cuyahoga valley, although not impossible, will require proper site evaluation, and more importantly, land-use planning if costly problems are to be avoided, and environmental compatability is to be assured.

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